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ABSTRACT

Studying the impact of economic growth on the environment in the context of developing countries has become of increasing economic importance in recent years. Alarming international reports show that pollutants emissions are growing at their highest level ever, particularly in the South countries. This paper implements recent bootstrap panel unit root tests and cointegration techniques to investigate the relationship between Sulfur dioxide emissions and real GDP for 12 MENA countries over the period 1981–2005. Our investigations lead to the result that no evidence is found for the EKC hypothesis for 10 country of the region. However, the EKC hypothesis is valid for the case of Egypt and Tunisia; the two most industrialised and diversified economies in our sample. At the same time, our findings show that EKC is not valid for the region when considered as a whole.

JEL Classification: C23, O11, Q25, Q28

Key words: Environmental Kuznets Curve, Sulfur Dioxide emissions, Economic Growth, panel data, MENA countries

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1. INTRODUCTION

Environmental Sustainability Index (ESI) report of 2005[1] suggests that most Middle East and North African (MENA) countries perform badly in environmental quality management. The same conclusion is found by the new version of the ESI called the Environmental Performance Index (EPI)[2] in 2010. According to this index, the MENA region can be divided into two distinct groups. The first one is composed of Algeria, Egypt, Iran, Jordan, Lebanon, Morocco, Syria and Tunisia. These countries perform relatively well in terms of environmental burden of disease and indoor air pollution. They also have roughly average results on most other indicators, but poor air pollution performance. Their scores on urban particulates and industrial carbon dioxide performance scores fall far below other clusters. The second group is composed of Bahrain, Libya, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Sudan and Yemen. This cluster is comprised of mainly fossil fuel producing and processing nations and too low-income countries. They perform well on the environmental burden of disease but poorly on outdoor air pollution. Their scores are among the lowest in some of the water indicators, but most notably, they have the worst greenhouse gas per capita performance of all the clusters.

Therefore, the question of sustainability of growth in MENA Countries is becoming central. On the one hand, environmental constraints may lead to lower the growth for the region in a context of a demographic boom associated with a high rate of unemployment. On the other hand, new opportunities and benefits from technological transfer may lead to better trend of growth and sustainability. One of the most important questions that arise in this context is to understand the nature of the relationship between economic growth and environmental quality in MENA countries.

According to the Environmental Kuznets Curve (EKC) hypothesis, as income increases, environmental degradation (emissions) increases as well until some threshold level of income is reached after which the environmental degradation begin to decline. An extensive literature has shown that the EKC hypothesis is validated for different local

[1] Between 1999 and 2005, the Yale and Columbia team published four Environmental Sustainability Index reports (http://sedac.ciesin.columbia.edu/es/esi/) aimed at gauging countries' overall progress towards "environmental sustainability".

[2] The 2010 EPI ranks 163 countries on 25 performance indicators tracked across ten well-established policy categories covering both environmental public health and ecosystem vitality. These indicators provide a gauge at a national government scale of how close countries are to established environmental policy goals. A pilot exercise was conducted in 2006 and a complete report was published in 2008.

pollutants in Organisation for Economic Cooperation and Development (OECD) countries. Thanks to their income per capita levels, most of OECD countries have shifted from the first branch of the curve to the second one in pollutants especially for local pollutants like Sulphur dioxide, PMP10, NOx and River pollutants. An extensive literature has discussed the theoretical foundation of such findings. The picture seems quite different for developing countries, especially Middle East and North African (MENA) countries, where findings are often inconclusive (see Arouri *et al.* (2012) and references therein).

Our article investigates the MENA countries as a region as well as at a country level by taking advantage of recent advances in the econometrics of non-stationary panel data econometric techniques and seemingly unrelated regression (SUR) methods. We choose to use sulphur dioxide (SO_2) emissions as the environmental quality proxy in order to test the existence of the Kuznets curve in the studied MENA countries. At least, three main arguments justify this choice. First, emissions of SO_2 are among the most important forms of energy-related pollution in the region. They originate primarily from stationary sources in the industrial and power-generating sector, and SO_2 emissions are known for their adverse effects on human health and the natural environment (EPA 2007). Second, although global sulphur emissions have increased over much of the last century, levels have begun to decline in recent decades. By 2000, global emission was approximately 25 percent lower than the peak level observed in the 1980s. Nevertheless, this decline was not homogenous across world regions. Whereas emissions are still rising in many developing countries, industrialized countries experienced an especially strong decline with emission reductions of more than 50 percent from 1970 to 2000. Obviously, it is important to understand if this decline is also observed in MENA Countries. Finally, SO_2 is produced by burning fossil fuels and is primarily emitted from stationary sources in the industrial generating sector (Olivier *et al.* 2005). Specifically, lignite and hard coal have high Sulphur contents so that their combustion is responsible for a large part of global SO_2 emissions. Yet, since the beginning of the 1970's, more end-of-pipe technologies, such as flue-gas desulfurization have been adopted to filter Sulphur dioxide. The existence of an EKC can reveals the extent to which MENA countries are adopting these new technologies.

Thus, the aims of our article are threefold. First, we check for the existence of EKC in the 12 countries belonging to MENA countries in matter of SO_2. Second, we assess the theoretical values of the turning points from which the economic growth improves the environmental quality in these countries. Third, we investigate the nature of the causality relationship between economic growth and emissions of SO_2.

The rest of paper is organised as follows. Section 2 surveys the theoretical foundation of the EKC and offers a synthesis of empirical studies on this topic. Section 3 presents the data, introduces the econometric methodology and discusses the empirical results. Section 4 recommends the appropriate policies and concludes.

2. LITTERATURE REVIEW

2.1. Theoretical explanations of the nature of the SO2-economic growth relationship

Generally the impacts of economic development on environment are disaggregated into three macro determinants: scale effect, technique effect, and composition effect (Grossman 1995; Copeland and Taylor 2004; Brock and Taylor 2006). The scale effect refers to the fact that increases in output require more inputs, and, as a by-product, imply more emissions. Economic growth therefore exhibits a scale effect that has a negative impact on the environment (Arrow, 1995). The technique effect refers to the invention of new technologies which are environmental friendly and to the application of these new technologies in production which in turn lead to the reduction of the pollution of the environment (Andreoni and Levinson, 2001). The impact of the technique effect is theoretically positive (de Bruyn 1997, Han and Chatterjie, 1997). The composition effect stems from changes in production of an economy caused by specialization (from agriculture or/and basic industries to high-tech services). All else equal, if the sectors with high emission intensities grow faster than sectors with low emission intensities, than composition changes will result in an upward pressure upon emission (Dasgupta, Mody, Roy, and Wheeler, 1995). The expected impact of the composition effect is positive deriving from the Rostow evolution postulate. Due to the different nature of these individual effects, the overall impact of growth on the environment is ambiguous (Grossman and Krueger (1991), Panayotou, (1997), and Cole (2004)).

Taking into account the nature of the Sulfur Dioxide as specific pollutant, several explanatory factors were proposed in order to explain the nature of the relationship between economic growth and SO_2 emissions: (i) the decomposition of the economy structure, (ii) adoption of new technologies and innovation, (iii) demographic factors like the structure of population or population density, (iv) environmental regulation, institutions and control system, and, (v) energy consumption structure.

According to De Bruyen (1997) change in industrial structure is the main factor affecting trends in SO_2 emissions. Stern (2004, 2005) asserts that changes in technology can lead with time to reductions in pollution-lowering of EKC- in both developing and developed countries. Case studies, particularly in China, show that pollution-reducing innovation and standards may be adopted with relatively short time lags in some developing countries. "Stern (2004) proposes that at middle-income levels, rapid growth can overwhelm these clean-up efforts, which have more effect in slower-growing higher income countries". Several articles show that population density is negatively correlated with sulfur dioxide emissions (Selden and Song, 1994, Cole and Neumayer, 2004 and Farzin and Bond, 2006). The main explanations are lower transportation requirements and higher environmental preferences in populated areas. Population compositional change has also considerable environmental policy implication. Recently, Menz and Kühling (2011) show that "societies with a low population and young and high proportion of senior citizens emit more Sulfur Dioxide". They verified these facts for 25 OECD countries from 1970 to 2000. In the same study, Menz and Kühling argue that three factors actually determine national SO_2 emissions: total national energy consumption, importance of fossil fuels with high Sulfur contents in the process of energy generation (energy mix), and usage of en-of-pipe technologies.

2.2. Empirical validation of the EKC hypothesis for sulfur dioxyde emissions

Sulfur emissions show the most typical environmental Kuznets curve among the air pollutants. A wide range of publications shows that SO2 EKC is empirically validated for most OECD countries. Since the findings of Selden and Song (1994) and Grossman and Krueger (1995) a plethoric literature has examined the EKC hypothesis for SO_2 at both regional and country levels. Stern (1998) claims that, in most OECD countries, the evidence for the inverted-U relationship is found only for a subset of environmental measures, e.g. air pollutants such SO_2 or suspended particulates. These findings are supported by those by Cole *et al.* (1997), Selden and Song (1994), Stern and Common (2001), Halkos (2003) and Markandya *et al.* (2006). Finally, Wang (2010) confirm the existence of Long-run Sulfur-income relationship for 19 OECD countries during the period 1870-2001.

Understanding past emission patterns in OECD countries has numerous insights for future emission projection especially in developing countries. One of the most important case studies is China. China has experienced rapid economic growth during last two decades and one can ask if this rapid growth has led to the validation of EKC for SO_2. Recent works find that even in developing countries like China, SO_2 emissions and GDP per capita are following an EKC. For instance, Gao *et al.* (2011) found that EKC is valid for SO_2 emissions for 29 Chinese provinces during the period between 2000 and 2008. Mou *et al.* (2011) establish for the same period that the relationship between economic growth and SO_2 emissions in the biggest city in China (Chongqing) is following an EKC. In contrast, Vincent (1997) shows that there is no confirmation of SO_2 EKC for Malaysia.

As for MENA countries, using cointegration analysis Chebbi *et al.* (2009) reveal a positive linkage between trade openness and per capita SO_2 emissions and a negative linkage between economic growth and per capita SO_2 emissions in the long-run. Fodha and Zaghdoudi (2010) provide support for a long-run N-shape relationship between per capita SO_2 emissions and per capita GDP. The authors confirm the EKC hypothesis. Akbostanci *et al.* (2009) study the relationship between SO_2 emissions, energy consumption and economic growth in Turkey at two levels: the national level and for the 58 Turkish provinces. The authors found a monotonic and increasing relationship at the national level. However, they found an N shaped curve at provinces level. Their findings do not support the EKC.

Regarding the turning point values, the results show a large dispersion across different studies. According to Lieb (2003) the reported turning points for SO_2 range from USD 2 900 to USD 98 200 (in PPP USD 1985). The calculations are very sensitive to the estimation methods and the econometrics used. Recent studies show that turning points for most OECD countries range from US$ 5 000 to US$ 10 000. Stern and Common (2001) show that the turning point in OCCD countries is US$ 9 000. Markandya *et al.* (2006) found a turning point at US$ 11 900 in 1990 PPP dollars. The turning points in non-OECD countries are extremely high and show unilateral increase for most of them.

Our work extends the finding of this literature by examining the situation in MENA countries at two levels: the whole region and the country level. Stern (2004) asserts that a large portion of EKC literature is statistically weak and when these statistical problems are taken into account and appropriate techniques are used, EKC cannot exist. We challenge this view in our paper and we show that using recent and appropriate econometrics leads to the existence of EKC for SO_2 in MENA Countries[3].

[3] Another concern is related to the environmental indicators' measurements. The "measures of the environmental degradation fall in two general categories: emission of the pollutants and environmental concentrations of pollutants" (Kaufman et al., 1998, p210). These two measurements illustrate different aspects of the environmental degradation situation and neither of them can offer a comprehensive description. "Emission directly measures the amount of pollutants generated by economic activities during a period without regarding to the size of the area into which the pollutants are emitted". It is actually a flow measurement for the polluting

3. DATA AND EMPIRICAL RESULTS

In what follows, after introducing the series of our data set we start by testing for unit roots in our variables. If the variables are non-stationary in our country panel, we test for the existence of long-run cointegration relationships and investigate their magnitude. Finally, we estimate panel error correction models (ECM) in order to examine the interactions between short- and long-run dynamics of our environmental variables.

3.1. Data set and panel unit root tests

We investigate the relationship between SO_2 emissions and GDP in MENA region using recent panel econometric methods. As several MENA countries have signed Kyoto protocol, there are still concerns regarding the environmental problems. To conduct our empirical analysis, we need the following variables for all studied MENA countries:

- the SO_2 emissions (S);
- the per capita real GDP (Y).

We collect data form World Bank Development Indicators (WDI). Our data are annual and cover the period 1981-2005 for the following MENA countries: Algeria, Bahrain, Egypt, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, Tunisia and UAE. The variables S and Y are measured in metric tons per capita and constant 2005 international dollar, respectively.

At first, we empirically investigate the following model based on variables in natural logarithms:

$$S_{it} = a_i + b_i Y_{it} + c_i Y_{it}^2 + \varepsilon_{it} \quad (1)$$

The coefficients *b* and *c* represent the long-run elasticity estimates of SO_2 emissions with respect to real GDP and squared real GDP, respectively. According to the discussion above, under the EKC hypothesis an increase in income is associated with an increase in SO2 emissions($b>0$) and there is an inverted U-shape pattern at which point an increase in income leads to lower SO_2 emissions ($c<0$).

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capacity of economic activities. "The concentration measures the quality of pollutants per unit area without regarding to the activity that emitted them", it is more like a stock measurement describing the final result of the encounter between emission, abatement efforts and the self-purification capacities of nature. As concentration is a more direct environmental quality indicator and has more direct impact on productivity and public health, Selden and Song (1994) believe it should be easier to obtain an inverted-U curve for concentration than for emission indicators.

The first step of the analysis is to look at the data properties. Two classes of tests allow investigating the presence of a unit root: The first generation panel unit-root tests (including Hadri, 2000; Im, Pesaran and Shin, 2003), were developed on the assumption of the cross-sectional independence among panel units (except for common time effects), and may be at odds with economic theory and empirical results. On the other hand, second generation tests (for instance, Choi, 2006; Moon and Perron, 2004) relax the assumption of cross-sectional independence, allowing for a variety of dependence across the different units. To test for the presence of such cross-sectional dependence in our data, we have implemented the simple test of Pesaran (2004) and have computed the CD statistic. This test is based on the average of pair-wise correlation coefficients of the OLS residuals obtained from standard augmented Dickey-Fuller regressions for each individual. Its null hypothesis is cross-sectional independence and is asymptotically distributed as a two-tailed standard normal distribution. Results available upon request indicate that the null hypothesis is always rejected regardless of the number of lags included in the augmented DF auxiliary regression (up to five lags) at the five percent level of significance. This confirms that the MENA countries are, as expected, cross-sectionally correlated, which can indeed reflect here the presence of similar regulations in various fields such as environmental policies, trade, customs, tourism, legislation, business administration, and increasing financial and economic corporation.

To determine the degree of integration of our series of interest (S, Y, and Y^2) in our panel of 12 MENA countries, we employ the bootstrap tests of Smith *et al.* (2004), which use a sieve-sampling scheme to account for both the time series and cross-sectional dependencies of the data through bootstrap blocks. The specific tests that we consider are denoted $\bar{t}$, $\overline{LM}$, $\overline{\max}$, and $\overline{\min}$. $\bar{t}$ is the bootstrap version of the well known panel unit root test of Im *et al.* (2003), $\overline{LM} = N^{-1}\sum_{i=1}^{N} LM_i$ is a mean of the individual Lagrange Multiplier (LM_i) test statistics, originally introduced by Solo (1984), $\overline{\max}$ is the test of Leybourne (1995), and $\overline{\min} = N^{-1}\sum_{i=1}^{N} min_i$ is a (more powerful) variant of the individual Lagrange Multiplier (LM_i), with $\min_i = \min(LM_{fi}, LM_{ri})$, where LM_{fi} *and* LM_{ri} are based on forward and backward regressions (see Smith et al., 2004 for further details). We use bootstrap blocks of m=20.[4] All four tests are constructed with a unit root under the null hypothesis and heterogeneous

[4] The results are not very sensitive to the size of the bootstrap blocks.

autoregressive roots under the alternative, which indicates that a rejection should be taken as evidence in favour of stationarity for at least one country.

The results, shown in Table 1 suggest that for all the series (taken in logarithms) the unit root null cannot be rejected at the five percent level of significance in our country panel for the four tests.[5] We therefore conclude that the variables are non-stationary in our country panel. [6]

Table 1a – Panel unit root tests of Smith *et al.* (2004) for S and Y, Y^2 (1981-2005)*

	Sulfur Dioxide Emissions (S)							
Test	Statistic (a)	Bootstrap P-value*	Statistic (b)	Bootstrap P-value*				
$\bar{t}$	-1.309	0.738	-2.021	0.685				
$\overline{LM}$	3.197	0.287	4.456	0.617				
$\overline{\max}$	-0.537	0.952	-1.610	0.750				
$\overline{\min}$	1.650	0.518	3.264	0.670				
	Per Capita Real GDP (Y)				Square of Per Capita Real GDP (Y^2)			
Test	Statistic (a)	Bootstrap P-value*	Statistic (b)	Bootstrap P-value*	Statistic (a)	Bootstrap P-value*	Statistic (b)	Bootstrap P-value*
$\bar{t}$	-1.521	0.492	-2.446 3	0.152	-2.393	0.187	-2.157	0.198
$\overline{LM}$	3.891	0.123	5.841	0.133	4.692	0.264	3.504	0.384
$\overline{\max}$	0.216	0.865	-0.685	0.974	0.327	0.846	-0.687	0.784
$\overline{\min}$	2.177	0.224	1.954	0.993	2.161	0.237	1.972	0.814

Notes: (a) Model includes a constant. (b) Model includes both a constant and a time trend.

* Test based on Smith et al. (2004). Rejection of the null hypothesis indicates stationarity at least in one country. All tests are based on 2,000 bootstrap replications to compute the p-values.

Null hypothesis: unit root (heterogeneous roots under the alternative).

3.2. Panel long-run relationship

Given that all the series under investigation are integrated of order one, we now proceed with the two following steps. First, we perform 2nd generation panel data cointegration tests (that allow for cross-sectional dependence among countries) to test for the existence of cointegration between S and Y, Y^2 contained in X. Second, if a cointegrating relationship

[5] The order of the sieve is permitted to increase with the number of time series observations at the rate $T^{1/3}$ while the lag length of the individual unit root test regressions are determined using the Campbell and Perron (1991) procedure.

[6] The lag order in the individual ADF type regressions is selected for each series using the AIC model selection criterion. Another crucial issue is the selection of the order of the deterministic component. In particular, since the cross-sectional dimension is rather large here, it may seem restrictive not to allow at least some of the units to be trending, suggesting that the model should be fitted with both a constant and trend. However, since the trending turned out not to be very pronounced, we have considered that a constant is enough in our analysis. Actually, the results of the bootstrap tests of Smith et al. (2004) are not very sensitive to the inclusion of a trend in addition to a constant in the estimated equation (see Statistic b in Tables 1). We have of course also checked using the bootstrap tests of Smith *et al.* (2004) that the first difference of the series are stationary, hence confirming that the series expressed in level are integrated of order one.

exists for all countries, we estimate for each country the cross-section augmented cointegrating regression

$$S_{it} = \alpha_i + \gamma_i X_{it} + \mu_1 \overline{S}_t + \mu_2 \overline{X}_t + u_{it}, \quad i = 1, \ldots, N; \quad t = 1, \ldots, T \quad (2)$$

by the CCE estimation procedure proposed by Pesaran (2006) that allows for cross-section dependencies that potentially arise from multiple unobserved common factors. The cointegrating regression is augmented with the cross-section averages of the dependent variable and the observed regressors as proxies for the unobserved factors. Accordingly, $\overline{S}_t$ and $\overline{X}_t$ denote respectively the cross-section averages of S and X_i in year t. Note that the coefficients of the cross–sectional means (CSMs) do not need to have any economic meaning as their inclusion simply aims to improve the estimates of the coefficients of interest. Therefore, this procedure enables us to estimate the individual coefficients γ_i in a panel framework.[7]

In addition, we also compute the CCE-MG estimators of Pesaran (2006). For instance, for the γ parameter and its standard error for N cross-sectional units, they are easily obtained as follows: $\hat{\gamma}_{CCE-MG} = \frac{\sum_{i=1}^{N} \hat{\gamma}_{i-CCE}}{N}$, and $SE(\hat{\gamma}_{CCE-MG}) = \frac{\sum_{i=1}^{N} \sigma(\hat{\gamma}_{i-CCE})}{\sqrt{N}}$, where $\hat{\gamma}_{i-CCE}$ and $\sigma(\hat{\gamma}_{i-CCE})$ denote respectively the estimated individual country time-series coefficients and their standard deviations.

We now use the bootstrap panel cointegration test proposed by Westerlund and Edgerton (2007). This test relies on the popular Lagrange multiplier test of McCoskey and Kao (1998), and makes it possible to accommodate correlation both within and between the individual cross-sectional units. In addition, this bootstrap test is based on the sieve-sampling scheme, and has the advantage of significantly reducing the distortions of the asymptotic test. Another appealing advantage is that the joint null hypothesis is that all countries in the panel are cointegrated. Therefore, in case of non-rejection of the null, we can assume that there is cointegration between S and its potential determinants contained in *X*.

[7] Note that in order to estimate the long-run coefficients we have also implemented the Pooled Mean Group (PMG) estimators (see Pesaran and Smith (1995), Pesaran, Shin and Smith (1999)), which allowed us to identify significant differences in country behaviour. However, we only report the results of the Common Correlated Effects (CCE) estimators developed by Pesaran (2006), since they allow taking unobservable factors into account, which would not be the case of the PMG estimators.

The asymptotic test results (Table 2) indicate the absence of cointegration. However, this is computed on the assumption of cross-sectional independence, not the case in our panel. Consequently, we also used bootstrap critical values. In this case we conclude that there is a long-run relationship between sulfur dioxide emissions and potential determinants, implying that over the longer run they move together.

Table 2 – Panel cointegration between sulphur dioxide emissions and potential determinants (1981-2005)

	LM-stat	Asymptotic p-value	Bootstrap p-value #
Model with a constant term	11.272	0.000	0.859

Notes: bootstrap based on 2000 replications.

a - null hypothesis: cointegration of sulphur dioxide emissions and potential determinant series.

Test based on Westerlund and Edgerton (2007).

3.3. Estimation of the long-run parameters

Given the evidence of panel cointegration, the long-run pollution income relations can be further estimated by several methods for panel cointegration estimation. We estimate the above equation to assess the magnitude of the individual γ_i coefficient in the cointegrating relationship with the CCE estimation procedure developed by Pesaran (2006), which addresses cross-sectional dependency.

$$S_{it} = \alpha_i + \gamma_{1i} Y_{it} + \gamma_{2i} Y_{it}^2 + u_{it}, \qquad (3)$$

with $i = 1,\ldots,N,\ t = 1,\ldots,T$, and the respective estimation results are reported in Tables 3.

Table 3 – Individual country CCE estimates for 12 MENA countries for the sulfur dioxide emissions and potential determinants (1981-2005)

Country	Y		Y^2		Constant	
	γ_1	t-Stat	γ_2	t-Stat	α_i	t-Stat
Algeria	1.105	2.342	-0.020	-2.513	2.754	2.115
Egypt	2.066	2.949	-1.08	2.569	5.551	2.781
Jordan	1.833	2.679	-0.841	-3.689	4.849	2.898
Lebanon	4.513	4.073	-2.203	-4.253	-4.136	-2.417
Morroco	1.102	3.826	-0.343	-2.598	-0.205	-2.532
Tunisia	1.430	4.218	-0.435	-1.959	5.539	8.508
Bahrain	0.829	3.890	-0.203	-2.335	-3.672	-1.912
Kuwait	-5.165	-4.787	2.179	3.405	-14.200	-5.190
UAE	-2.310	-2.826	0.778	2.129	11.713	5.117
Oman	4.657	3.571	-1.490	-2.282	5.295	3.616
Qatar	-2.964	-2.715	1.813	2.772	-10.205	-5.818
Saudi	1.037	2.465	-0.352	-3.770	-4.734	-4.574

Note the coefficients of the variables $\overline{E}_t$ and $\overline{X}_{1t}$ of equation (2) have not been reported in the table.

The results show that there are an inverse U-shaped relationships between per capita pollution and per capita GDP for all studied MENA countries, expect Kuwait, UAE and Qatar. For Tunisia, the elasticity is 1.430-0.870Y with the threshold income of 1.644 (in logarithms). EKC hypothesis seems to hold in this case. We reach the same conclusion in the case of Egypt. However, for Algeria the elasticity of SO_2 emissions per capita with respect to real GDP per capita in the long-run is 1.105-0.04Y with the threshold income of 27.625 (in logarithms) which is very high (when transformed in dollars) compared to its level of real GDP in that period. In contrast, for Saudi Arabia, the elasticity of SO2 emissions with respect to real GDP is 1.037-0.704Y, implying a threshold income of only 1.473 (in logarithms), which is very low compared to the Saudi real GDP.

Therefore, we have to point out that for most countries where we found an EKC, we are confronted to the problem of the position of the threshold compared to the level of real GDP reached by each country during the period. Our calculations lead us to conclude that none of the studied cases verified this particular EKC hypothesis except Egypt and Tunisia.

Egypt noticed a remarkable improvement in sulfur dioxide concentrations during the first years of the 2000, whereas daily average concentrations were ranged between 20-40 µg/m3 which is lower than the limit stated in the Executive Regulation of Environment Law 4 /1994 (150 µg/m3). This improvement is due to the efficient use of fuel in power stations and industrial sector, reducing diesel fuel usage in these sectors and expands in natural gas usage.

The actions related to rationalisation of energy use in Tunisia were mainly focused on stepping up the actions of mandatory and periodic energy audits and signing performance contracts in the industry, transport and services sectors. Since the end of the nineties, pilot projects in the field of energy conservation were implemented in the housing and services sectors, and encouraging the use of energy saving equipments, appliances and materials. Besides, several programmes were pursued in relation to cogeneration in the industry sector, energy efficiency in street lighting networks, and rationalisation of energy use in the administration and public facilities. Also, as part of implementing the State policy in the field of energy substitution and directing consumption towards less costly energy, effort was invested in pursuing the programme of promoting the use of natural gas as a fuel in the transport sector and fostering the use of natural gas powered air conditioning in the services sector.

Finally, the results from the common correlated effects mean group (CCE-MG) method are reported in Table 4.

Table 4 – Results for common correlated effects mean group (CCE-MG) estimations, 12 MENA countries (1981-2005) for SO_2 emissions

	(1) X= (Y, Y^2)
Constant	-3.42
	(-2.76)
Y	0.250
	(5.28)
Y^2	-0.027
	(-4.37)

Note: t-statistics are in parentheses.

The last table shows that the elasticity of SO_2 emissions per capita with respect to real GDP per capita in the long-run is 0.250–0.054Y with the threshold income of 4.630 (in logarithms), which is not supportive of the EKC hypothesis in the MENA region. This result was expected given the number of countries producing oil and gas in our sample[8].

3.4. Estimation of a panel error-correction model

In the previous sub-section, we have estimated the long-run relationships between S and Y, Y^2 for our panel of 12 MENA countries, using the common correlated effects mean group (CCE-MG) estimates (see Tables 4). Having established the long-run structure of the underlying data and given that there exists a long-run relationship for all countries in our four panel sets, we turn to the estimation of the complete panel error-correction model (PECM) described by equations (5):

$$\Delta S_{it} = \sum_{j=1}^{p} \beta_j \, S_{it-j} + \sum_{j=0}^{p} \theta_j \, \Delta X_{it-j} + \lambda_i [S_{it-1} - \alpha - \gamma \, X_{it-1}] + \varepsilon_{it}, \qquad (5b)$$

We use the Pooled Mean Group (PMG) approach of Pesaran, Shin and Smith (1999), with long-run parameters obtained with CCE techniques, in order to obtain the estimates of the loading factors λ_i (weights or error correction parameters, or speed of adjustment to the equilibrium values), as well as of the short-run parameters β_j and θ_j for each country of our panel. Consequently, the loading factors and short-run coefficients are allowed to differ across countries.[9]

[8] The burning of fossil fuels is the most significant source of air pollutants such as SO_2, CO, certain nitrous oxides such as NO and NO_2 (known collectively as NO_x), SPM, volatile organic compounds (VOCs) and some heavy metals. It is also the major anthropogenic source of carbon dioxide (CO_2), one of the important greenhouse gases.

[9] Note that before considering equation (3), we first used a Wald statistic to test for common parameters across countries (i.e $\lambda_i = \lambda$, and $\gamma_i = \gamma$, for i=1,...,N) with the CCE techniques of Pesaran, (2006), that allow common factors in the cross-equation covariances to be removed. We found that only the null hypothesis $\gamma_i = \gamma$, for i=1,…,N was not rejected by data, whereas the speeds of adjustment λ_i vary considerably across countries (results are available upon request).

The lag length structure p is chosen using the Schwarz (SC) and Hannan-Quinn (HQ) selection criteria, and by carrying out a standard likelihood ratio testing-down type procedure to examine the lag significance from a long-lag structure (started with $p=4$) to a more parsimonious one. Afterwards, in order to improve the statistical specification of the model, we implemented systematically Wald tests of exclusion of lagged variables from the short-run dynamic (they are not reported here) to eliminate insignificant short-run estimates at the 5% level. We tested the residuals from each PECM model for the absence of heteroscedasticity, autocorrelation, and we can report that they are not subject to misspecification. The results of the PECM estimations based on (5) are reported in Tables 5, only for significant short-run estimates at the 5% level.

Table 5 – Panel Error-Correction estimations for S_{it}, X= (Y, Y^2), (1981-2005)

	D S_{it-1}	DY_t	DY_{it-1}	D Y^2_{it}	D Y^2_{t-1}	Loading factor λ_i
Algeria	0.40 (2.08)	0.41 (3.14)	-	-0.015 (-2.76)	-0.10 (2.82)	-0.52 (-4.95)
Egypt	-	0.55 (2.23)	-	-0.21 (-4.48)	-0.04 (-2.72)	-0.86 (-3.22)
Jordan	-	0.57 (2.76)	-	-0.18 (-4.36)	-0.05 (-3.37)	-0.76 (-4.13)
Lebanon	-	0.58 (1.98)	-	-0.17 (-4.76)	-0.03 (-3.18)	-0.81 (-3.38)
Morroco	-	0.43 (2.21)	-	0.13 (3.77)	-0.09 (-2.85)	-0.78 (-5 .72)
Tunisia	-	0.15 (2.13)	-	-0.05 (-2.39)	-	-0.27 (-2.75)
Bahrain	0.28 (2.48)	0.10 (2.10)	0.07 (2.91)	-0.03 (-2.53)	-	-0.14 (-2.62)
Kuwait	-	0.05 (2.63)	-	-0.21 (-4.48)	-0.01 (-2.28)	-0.65 (-3.41)
UAE	-	0.31 (4.42)	-	-0.38 (-5.25)	-	-0.05 (-2.72)
Oman	-	0.21 (3.21)	-	-0.21 (-4.48)	-	-0.58 (-3.27)
Qatar	-	0.25 (2.74)	-	-0.22 (-3.79)	-0.07 (5.14)	-0.45 (-5.21)
Saudi	-	0.22 (2.16)	-	-0.08 (-2.82)	-0.07 (-2.94)	-0.40 (-3.52)
CCE-MG	intercept	Y	Y^2			
	-3.19 (-6.15)	0.37 (4.19)	-0.21 (-4.48)			

Notes: The estimations are obtained from the Pooled Mean Group approach with long-run parameters estimated with CCE techniques. The coefficients of the variables $\overline{E}_t$ and $\overline{X}_{1t}$ of equation (2b) have not been reported in the table. t-statistics are in brackets. S– Sulfur Dioxide Emissions; Y – Per Capita Real GDP; Y^2 – Square of Per Capita Real GDP.

Results from Table 5, allow checking for two sources of causation: (1) the lagged difference terms (short-run causality) and/or (2) the error correction terms (long-run causality). The causality from GDP to SO_2 emissions depend on the level of economic growth. As for the long-run dynamics, the loading factor, which measures the speed of adjustment back to the long-run equilibrium value, is significantly negative in all cases confirming that all the variables of our model move together over the long run. Thus, the long-run equilibrium deviation has a significant impact on the growth of SO_2 emissions.

Table 6 - EKC for SO_2 in the MENA region (1981-2005)

Country	Intercept	Inverted U shape curve	Turning point	Ymin	Ymax	EKC
Algeria	1.105 - 0.040 Y	Yes	Very high	5 530	7 176	No
Egypt	2.066 - 2.160 Y	Yes	2 651	2 460	4 318	**Yes**
Jordan	1.833 - 1.682 Y	Yes	2 971	3 032	4 360	No
Lebanon	4.513 - 4.406 Y	Yes	2 784	6 565	20 368	No
Morocco	1.102 - 0.686 Y	Yes	4 983	2 254	3 588	No
Tunisia	1.430 - 0.870 Y	Yes	5 175	3 602	6 444	**Yes**
Bahrain	0.829 - 0.406 Y	Yes	7 706	16 648	28 069	No
Kuwait	-5.165 + 4.358 Y	No	-	22 873	44 354	No
UAE	-2.310 + 1.556 Y	No	-	41 862	90 478	No
Oman	4.657 - 2.980 Y	Yes	4 773	10 269	19 544	No
Qatar	-2.964 + 3.626 Y	No	-	43 705	77 232	No
Saudi	1.037 - 0.704 Y	Yes	4 362	18 243	34 116	No
12 countries	0.250 - 0.054 Y	Yes	102 514	2 254	90 478	No

4. CONCLUSION AND POLICY IMPLICATIONS

Our article had three aims. First, we investigated the existence of EKC for the MENA region taken as a whole in the matter of Sulfur dioxide. Second, we tested for the existence of EKC for each country. Finally, we explored the nature of the causality relationship between economic growth and emissions of SO_2. Compared to previous works, we took advantage of implementing more robust and recent bootstrap unit root tests and panel cointegration techniques to investigate the relationship between economic growth and SO_2 emissions in MENA countries.

Departing from the hypothesis that the 12 countries are homogenous and looking at the regional-level, our results reject the EKC hypothesis for the MENA region. This finding can be explained by at least three complementary arguments. First, although most of MENA countries have built recently a capacity to manage environmental problems and, especially, air pollution, the non-decline of SO2 emissions as GDP increases may be explained by corruption (Leitao, 2010). In his study, Leitao found an inverted U-shaped curve between Sulfur dioxide and economic growth. However, the author suggests that different income-pollution paths across countries are found due to corruption. Most of the considered countries perform badly in matter of corruption. While laws in matter of Air pollution exist, the enforcement of laws and control are ineffective due to corruption.

Second, contrary to CO_2 emissions that are more linked to consumer behaviour and are non-source pollution, SO_2 emissions are more closed to producers' behaviour and are local pollutant. The non-decline of SO_2 in MENA countries can be explained also by little or absence of change in matter of adoption of new technologies (end-of-pipe technologies). While, in OECD countries there is a fall in SO_2 emissions due to massive adoption of new technologies in matter of desulfurization, this is not the case in most of MENA countries. Changes in the technological behaviour may lead in the near future to a change in the relation between economic growth and SO_2 emissions.

Moreover, the rapid growth of energy demand and especially for electricity generation may explain poor performances in matter of SO_2 reduction in MENA countries. It is well known that electricity generation plants emit high levels of Sulfur dioxide. MENA countries are facing or will face shortage in this domain. As Krane (2010) states "for the six states of Golf Cooperation Council (GCC)…are unable to meet their own fast rising demand for domestic energy, mainly natural gas feedstock for electricity generation." These countries are going to face shortage in the near future due to their fast demand in matter of energy[10]. Energy conservation options are envisaged. Some GCC countries are investing in nuclear power to generate energy and other MENA countries are investing in renewable energy generation (Ghaddar, 2010).

Third, most of the considered countries are based on primary sector (Rentier States[11]) and their move toward a service economy is low. They have not yet reached a positive regime where the effect of growth on SO_2 emissions is environmental improving. The economic composition of these economies is changing slowly. Some non-oil countries like Egypt and Tunisia are changing their structural economic composition and are performing better than the other countries in the sample.

[10] Qatar is an exception among these countries.
[11] The term Rentier States connotes a country that derives most of its national income from the external sale of natural resources.

At the country-level, our results show that EKC is not verified for the studied countries except Egypt and Tunisia. Our results confirm those by Fodha and Zaghdoudi (2010) using a different methodology. The authors show an evidence for Sulfur Dioxide EKC for Tunisia. Their main explanation relies on the enforcement of laws and the effectiveness of the control of plants, which are responsible of SO_2 emissions. The Economic structure of Tunisia dominated by services may also explain this result. In the case of Egypt, the result is explained by technological change and adoption of new technologies. In fact, Egypt has shifted to cleaner technology in matter of electricity generation. Generation plants are more using gas and less burning oil. This shift and more effective regulation lead to an improvement of the situation. Our results show that for these two countries the values of the turning points are very close to those found for OECD countries.

In the case of Gulf Cooperation Council countries (GCC), the shift towards more energy efficiency could improve their performance (Doukas *et al.*, 2006). These countries are exploring new policies, but this reorientation has not yet resulted in the development of consistent strategies and policies (Reiche, 2010). At the same time, one must mention that several initiatives of renewable energy were taken in Algeria, the kingdom of Saudi Arabia and other MENA countries like the pioneering project of Masdar Sustainable City[12]. These initiatives are expected to improve the situation in the next years. Actual efforts and policies changes are not captured by actual statistics and, the EKC is not verified at the country level in most cases. However, we think that all these initiatives are improving the situation.

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[12] MENA countries are estimated to have a potential to generate 630,000,000 megawatts of solar power and also 75000 megawatts of wind power potential (Ghaddar, 2009).

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